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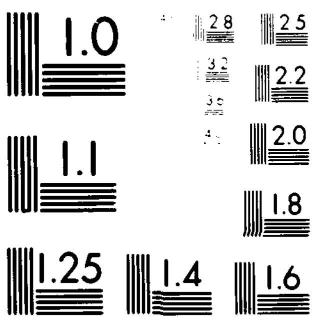

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INVESTIGATION IN OPTICAL GUIDED WAVES
Final Report

. Yeh

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Final Technical Report to

OFFICE OF NAVAL RESEARCH
Code 427, Electronics Program
Attention: Dr. Henry Mullaney

for

INVESTIGATION IN OPTICAL GUIDED WAVES

(Contract N00014-76-C-0321)

PRINCIPAL INVESTIGATOR:

Cavour Yeh
Professor
Electrical Engineering Department

December 1980

Submitted by

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA
UNIVERSITY OF CALIFORNIA, LOS ANGELES
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Abstract

This report summarizes the results of the research carried out at the Electrical Engineering Department of the University of California at Los Angeles under contract ~~N00014-76-C-0321~~ with the Office of Naval Research. The research dealt in general with the problems associated with the propagation and guidance of optical waves along or in complex dielectric structures.

I. Introduction

This is a final report on a study sponsored by the Office of Naval Research (N00014-76-C-0321) and conducted in the Electrical Engineering Department of the University of California, Los Angeles. This research effort is concerned with the theoretical and experimental investigations on the wave-guiding or wave-amplification characteristics of various passive or active dielectric structures with special emphasis on applications in integrated optics, fiber optics and millimeter wave devices.

Five problem areas have been treated within the life-time of this contract resulting in the publication of 14 technical papers and 8 conference presentations.

II. Summary of our accomplishments.

We shall summarize our accomplishments in the following:

A. Analysis of single-mode or multimode inhomogeneous dielectric guiding structures - The scalar wave - fast Fourier transform approach.

Yeh, C., "Coupling of Multimode Fiber Structures," SPIE Publication, 139, 1978.

Yeh, C., Casperson, L. and Szejn, "Propagation of Truncated Gaussian Beams in Multimode Fiber Guildes," J. Opt. Soc. Am. 68, 989-993, 1978.

Yeh, C., W. P. Brown and R. Szijn, "Multimode Inhomogeneous Fiber Couplers," Appl. Opt. 18, 489-497, 1979.

Yeh, C., W. P. Brown and L. Casperson, "Scalar Wave Approach to Single-mode Problems for Inhomogeneous Fibers on Integrated Optical Circuit Structures," Appl. Phys. Lett. 34, 460-465, 1979.

B. Guided waves.

Yeh, C., "Modes in Weakly Guiding Elliptical Optical Fibers," Optical and Quantum Electronics, 8, 43-47, 1976.

Yeh, C. and Lindgren, G., "Computing the Propagation Characteristics of Radially Stratified Fibers: An Efficient Method," Applied Optics, 16, 483-493, 1977.

B. Guided waves. (Continued)

Yeh, C. and Johnston, A., "How Does One Induce Leakage in an Optical Fiber Link," AGARD Proceedings in Optical Fiber, Integrated Optics and Their Military Applications, May, 1977.

Yeh, C. and Brown, W.P., "Modeling of Star-shaped and Parallel-wire Carrier Distribution Systems," J. of the Franklin Institute, 305, pp. 67-78, February 1978.

Yeh, C., Manshadi, F., Casey, K.F. and Johnston, A., "Accuracy of Directional Coupler Theory in Fiber or Integrated Optics Applications," J. Opt. Soc. Am., 68, 1079-1083, August 1978.

Yeh, C., "Optical Waveguide Theory," IEEE Trans. on Circuits and Systems, CAS-26, 10011-1021, 1979 (invited paper).

C. On arbitrarily shaped, inhomogeneous, optical waveguides - The finite-Element approach.

Yeh, C., K. Ha and S. Dong, "Single-mode Optical Waveguides," Appl. Opt. 18, 1490-1501, 1979.

D. Low-noise fiber-optics receiver.

Knorr, S.G., O. Kaldirin and C. Yeh, "low-Noise Fiber Optics Receiver with Super-Beta Bipolar Transistors," Fiber and Integrated Optics, 1, 369-386, 1978.

E. Active fiber waveguides.

Imminent perfection of low-loss optical fiber cables as wide-band communication lines is one of the most important engineering achievements in the '70s. Even though fiber cable losses less than 2 dB/km are achievable, periodically spaced repeaters boosting the strength of the optical signal in the fiber must still be used for long-distance transmission. Amplification of the optical signal by the repeater scheme is limited to first detecting the optical signals by photodiode, amplifying the detected and demodulated signals electronically with low-noise amplifiers, and then using the amplified electronic signal to modulate the driver of an optical source which provides the necessary boosted optical power for the fiber cable. It is conceivable, however, that amplification of the optical signal may

be achieved directly. We are in the process of implementing a conceptually simple scheme which can be used to amplify directly the optical signal along a fiber guide. In this scheme an optical amplifier is made an integral part of the optical fiber channel by either diffusing active material into the optical fiber or surrounding the optical fiber with the active material.

We have partitioned our research investigation in two parts: analytical tasks and experimental tasks. The experimental investigation deals with two basic experimental setups and their variance, while the analytical investigation deals with the analyses of various active dielectric guiding structures.

(1) Experimental Tasks on Active Waveguides

(a) Active Fiber Structures

When a section of glass fiber is doped with active material, such as neodymium ions, and is pumped by an external flashtube, amplification of the light signal guided by the glass fiber may occur.

Consideration is given to the added losses at the input-output transition region as well as losses due to the curvatures of the active fiber. Furthermore, the dispersion characteristics of an active fiber are yet unknown. To obtain accurate measurement of the amplified optical signal, one must eliminate any stray light from the flashtube which may enter the cladding of the fiber.

(b) Passive Fibers Immersed in Active Medium

Another way of achieving light amplification along fibers is to immerse the core of a fiber in an active medium, such as a liquid solution of neodymium oxide (Nd_2O_3) dissolved in selenium

oxychloride ($SeOCl_2$) acidified with tin tetrachloride ($SnCl_4$) or a solution of organic fluorescent dyes.

Again consideration must be given to the added losses at the input-output transition region, the curvature losses as well as the dispersion characteristics of the amplifying structure.

(c) Variations of the Above Experiments

It is well known from electromagnetic theory that distributed reflections occur from corrugated structure. Hence. if periodic corrugations were applied to the surface of the active fiber in (1) or to the surface of the passive fiber core in (2), distributed feedback laser action should occur to enhance the amplification of the input signal.

(2) Analytical Tasks on Active Waveguides

Very little analysis had been carried out for the active waveguide problems. Almost nothing is known for the problems related to the experimental tasks mentioned in the previous section. We have initiated work in the following areas:

(a) gain and dispersion characteristics of a circular fiber with an active core;

(b) gain and dispersion characteristics of a circular fiber immersed in an active medium;

(c) gain and dispersion characteristics of a corrugated active fiber or corrugated fiber immersed in an active medium;

(d) coupling characteristics of two parallel fibers surrounded by gain medium.

We expect to publish our results.

III. PERSONNEL

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Geoffrey Mariki (Graduate Student)
Farzin Manshadi (Graduate Student)
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the results of the research carried out at the Electrical Engineering Department of the University of California at Los Angeles under contract N00014-76-C-0231 with the Office of Naval Research. The research dealt in general with the problems associated with the propagation and guidance of optical waves along or in complex dielectric structures.

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